OPTIMIZATION OF PRESSING TIME FOR THE QUALITY GRADE FIBERBOARD MADE FROM AGRO-WASTE COCONUT COIR FIBER

Saw Win[1], Win Win Nu[2], Myint Sandar Win[3]

Abstract

In the present work, it was aimed to investigate the effect of pressing time on the properties of fiberboards. Fiberboards were fabricated from agro-waste coconut coir fiber treated with 1% aqueous solution of commonly used fiber modifier known as sodium hydroxide and 25% urea-formaldehyde (UF) adhesive by hot press molding technique. Furnish (mixture of particle and resin) was placed in hot press machine at 150˚C and 2200psi for pressing time 10,15,20 and 25 minutes. The properties of fibreboard panels were determined according to methods described in British Standard (BS), Indian Standard (IS) and American Society for Testing Materials (ASTM) methods. The result showed that 25 minutes was the optimized pressing time for resulting of physical and mechanical properties of fibreboard. Almost all those properties had fulfilled to the requirements for JSA, (JIS-A5908-2003) and FAO (2013) standard values. The pressing time is one of the controlling factors for the quality grade fibreboard.

Keywords: Pressing time, agro-waste coconut coir fiber, urea-formaldehyde, hot press molding technique, properties

Introduction

Nowadays, due to forest production and environment awareness, the use of natural wood is steadily decreasing. Technology is used to manufacture valuable materials from agricultural waste which is considered to substitute natural wood. For coconut coir fiber (*Cocos nucifera*) which is the seed-hair fiber obtained from the outer shell or husk of the coconut. The chemical composition of coconut coir fiber was 43.44 % cellulose, 0.25 % hemi-cellulose, 45.84 % lignin, 2.22 % ash, 3.00 % pectin and related compounds. It contains high lignin ratio (45.84 %) that makes fibers stiffer and tougher. The stiff and tough fibers are difficult to beat, do not conform and collapse against each other so well. That would like impact manufacturing process and properties (website1). According to that fact, coconut coir fibers have potential as raw materials for fiberboard manufacturing. Utilization of coconut coir fiber to produce of fiberboard will increase added value to raw materials. However, some problems will occur in using of agriculture waste such as voluminous and hydrophilic properties. Bulky materials and hydrophilic properties will cause to storage problems and in dimensional stability, lower durability to termite attack and lower the mechanical properties of board.The adhesive used in commercial wood and non-wood fiberboard products are usually synthetic polymer resin, based in the condensation reaction of formaldehyde with phenol, urea, resorcinol or melamine. It processed better water resistance and strength than natural adhesive (Dellollis, 1980). Urea-formaldehyde (thermosetting polymer) is the commercial resin popularly used for wood-based and non-wood-based panel product (Lee *et al*, 2011).

Particle board also known as particleboard, low density fiberboard (LDF) and medium density fiberboard (MDF). In almost all the cases, this means particleboard or MDF or similar. Particleboard (Fiberboard) is a wood-based or non-wood-based panel product manufactured under pressure and temperature from

[1]Dr. Associate Professor, Department of Engineering Chemistry, West Yangon Technological University.
[2]Dr. Associate Professor, Department of Botany, Myeik University.
[3] Dr. Professor (Head), Department of Engineering Chemistry, West Yangon Technological University.

the particles of wood or other lignocellulosic fibrous materials and binder (Garacia ortumo, 2011). Fiberboards are intended for use as interior furnishing, including furniture at dry condition. If laminates or furniture foil is properly affixed to the board surface, particleboards can also be used in the production of furniture that can be exposed to the action of higher humidity such as laundries, bathrooms and kitchens (Wazy, 1994). The objective of this research was to evaluate the effect of pressing time on the properties of fiberboard made from coconut coir fiber.

Materials and Methods

Materials

Coconut husk raw were collected from Tamwe market, Tamwe Township, Yangon, Myanmar. Urea-formaldehyde (UF) was obtained from Watayar Glue Factory, Yangon, Myanmar. To obtain the best fiberboard made from coconut coir fiber, the fiberboard manufacturing condition was made available as shown in Table 1. The coconut husk raw and coconut coir fiber were shown in Figure 1(a,b).

Figure 1(a) Coconut Husk Raw

Figure 1(b) Coconut Coir Fiber

Table 1. Fiberboard Manufacturing Condition

No.	Condition
1. Board size	(15.24 ×15.24) cm^2
2. Density target	1.0 gcm^{-3}
3. Adhesive	UF (25 %) Solid content (58 %)
4. Fiber particle Coconut Coir Fiber	Particle size (500 µm), 100 g Moisture content (14.49%) Treated with 1 % NaOH
5. Hot press	Temperature: (150 ˚C) Time: 10, 15, 20, 25 (minutes) Pressing Pressure: 2200 psi
6. Pressing Schedule	One step pressing schedule

Methods

Fiber Extraction and Alkali Treatment

Coconut husks were soaked in water for 15 days to loose fibers from each other in the shells. Fibers were extracted by hand stripping (Retting process). The extracted fibers were washed with water three times to remove dust and other impurities. The washed fibers were soaked in 1 % sodium hydroxide for 1 hour followed by soaked in very dilute acetic acid to neutralize excess sodium hydroxide. By treating fibers with this base, the wax and oil existed on the wall of fiber were removed and tend to rough the surface of fiber for good bonding with matrix resin. The treated fibers were washed with water two times to remove the last traces of acid sticking to it and dried in ambient temperature to reduce moisture content for one week and to get alkali treated fiber.

Fiberboard Manufacturing

Single layered fiberboard was produced with the size of (15.24 × 15.24 × 0.5) cm^3 and target density was (1 gcm^{-3}). Hensel mixer was used for mixing coconut coir fiber particles and UF adhesive. Furnish (mixture) was then placed in hot press machine (LJT – 91556, APEX CONSTRUCTION LTD, GRAVESEND, ENGLAND). Two boards were prepared for each treatment.

Determination of Physical and Mechanical Properties

Firstly, specimens were conditioned for 7 days at ambient temperature to determine physical and mechanical measurements. The board quality was assessed using physical parameters on density, moisture content (MC), water absorption (WA) and swelling thickness (ST) which were determined by (BS:1811-1961) British Standard and (IS:3087-1965) Indian Standard methods. The mechanical parameters of boards such as modulus of rupture (MOR), impact strength and hardness were also determined by their respective methods. The dimension of specimens for evaluation in density and moisture content of boards were (2.54 × 2.54) cm^2. The specimens were weighed and measured immediately after oven-dried at 100 ± 2˚C until they reached constant weight and measurements. The WA and ST were also determined with the specimens size of (2.54 × 2.54) cm^2. The specimens were soaked in water for 24 hours. After 24 hours of immersion (or) submersion, specimens were dripped and wiped for cleaning of any surface water, the weight and size of specimens were measured. Average thickness was determined by taking several measurements at specific locations.

Mechanical properties (MOR, impact strength and hardness) were tested by using. American Society for Testing Materials (ASTM D-412) and (ASTM D-256) methods. The dimension of specimens in MOR test and impact strength test were (14.80 × 2.54) cm^2. For hardness test, the dimensions of specimens were (1.50 × 1.50) cm^2. Evaluation of MOR, impact strength and hardness parameters were done at ambient temperature. The all resulted obtained were shown in Table 2.

Results and Discussion

The four types of coconut coir fiberboard (FBt1-FBt4) were prepared by varying the pressing time (10, 15, 20, 25) min and other parameters were fixed Figure 2.

Figure 2 Prepared fiberboards

Table 2: The Physical and Mechanical Properties of Prepared Fiberboards at Different Pressing Times

Properties	FBt1	FBt2	FBt3	FBt4	Reference **Reported
Thickness (cm)	0.47	0.53	0.50	0.45	-
Density (gcm^{-3})	1.00	0.97	1.09	1.07	0.40 - 0.90 (JSA)
Moisture content (%)	6.85	6.50	6.40	6.11	5 – 13 (JSA)

Water absorption*(%)	55.66	56.62	54.99	46.05	20-75
Swelling thickness*(%)	51.81	57.77	44.49	37.56	5-15
Modulus of rupture (psi)	6569.16	5243.55	6341.37	7102.67	-
Modulus of rupture (kg/cm^2)	461.86	368.66	445.84	499.37	100-500
Impact strength (Kjm^{-2})	136.53	138.37	111.57	77.23	-
Hardness (Shore A)	90.95	94.35	88.45	86.87	-

Pressing temperature = 150°C pressing time = 10, 15, 20, 25 min
Pressing pressure = 2200 psi Fiber type = coconut coir fiber
Adhesive type = UF
* = after soaking period 24h
** = FAO (2013), JSA (2003)
FAO = Food and Agriculture Organization
JSA = Japanese Standard Association
FBt1 = Fiberboard prepared at 10 min pressing time
FBt2 = Fiberboard prepared at 15 min pressing time
FBt3 = Fiberboard prepared at 20 min pressing time
FBt4 = Fiberboard prepared at 25 min pressing time

Physical Properties

The density range of prepared fibreboards made from coconut coir fiber and UF was (0.97 – 1.09) gcm^{-3}.

There are several factors that influencing of board density were wood density, pressing pressure, particle quality in mat, resin content, and other additive (Kelley, 1997). The density value in this research work was slightly greater than JIS A5908-2003 standard value of 0.4 to 0.9 gcm^{-3} (JSA, 2003). Bowyer *et al*. (2003) stated that density of fibreboard is higher than the original material components, due to resin weight, additive and pressure during manufacturing. It was expected that increasing pressing temperature tend to decrease the density of boards due to the decreasing moisture content (or) free water.

Moisture content (MC) values of prepared fiberboards made from this fiber and adhesive type was from 6.11% to 6.85 % as shown in Figure 3.

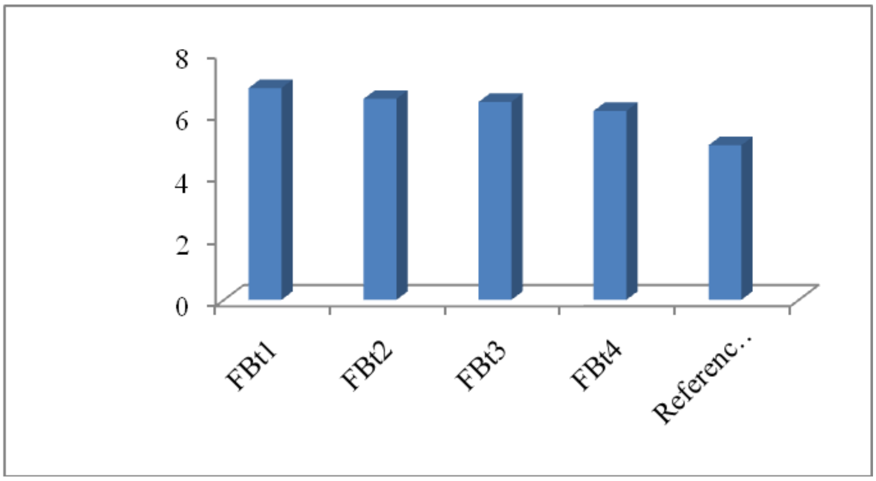


Figure 3 Moisture content of fiberboards

Moisture content (MC) value in this research was influenced by density and pressing time. Fiberboard with lower density will cause water or water vapour more easily to be absorbed or released into fibreboard. Figure 3 showed that the increase in pressing time at the same pressing temperature will reduce the MC of fibreboard. Heebink *et al*, (1972) showed that the decreasing pressing time at the same temperature caused the increase in MC. Several factors that influencing of MC are particle MC and environment condition fibreboard conditioning. The MC values of prepared fibreboards had fulfilled of JIS A5908-2003 (JSA 2003) that requirement of MC is 5-13 %. The lowest MC of fibreboard (FBt4) had the best quality due to the lowest MC value of 6.11 %.

Water absorption (WA) value of prepared fibreboard were shown in Figure 4 and swelling thickness (ST) value of boards were also shown in Figure 4.

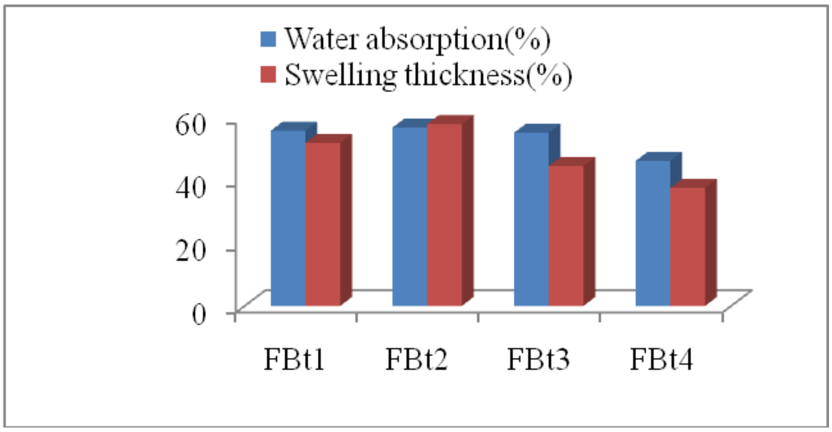


Figure 4 Water absorption and swelling thickness of fiberboards

Winandy and Krzysik (2007) reported that increasing of pressing temperature and time does not resist medium density fibreboard to absorb of water. Hemicellulose is the most responsible to WA compared to cellulose and lignin. WA value of boards had fulfilled of FAO (2013) which requirement of maximum WA is 75 %. The fibreboard (FBt4) with lowest WA value of 46.05 % is the best quality grade fibreboard among the prepared fiberboards.

The high temperature 150˚C for longer time 25 minutes will cause over curing on resin, so that it will be resulting of lowering in bonding strength. Guler *et al*, (2008) reported ST of wood panels were influenced by quality and distribution of adhesive, MC of furnish, furnish compatibility, chemical composition of furnish, etc. ST value of prepared fiberboard had not fulfilled to FAO (2013) that requirement of maximum ST value is 15 %.

Mechanical Properties

Modulus of rupture (MOR) value range of prepared fibreboard was 368.66 – 499.37 kgcm^{-2} as shown in Figure 5.

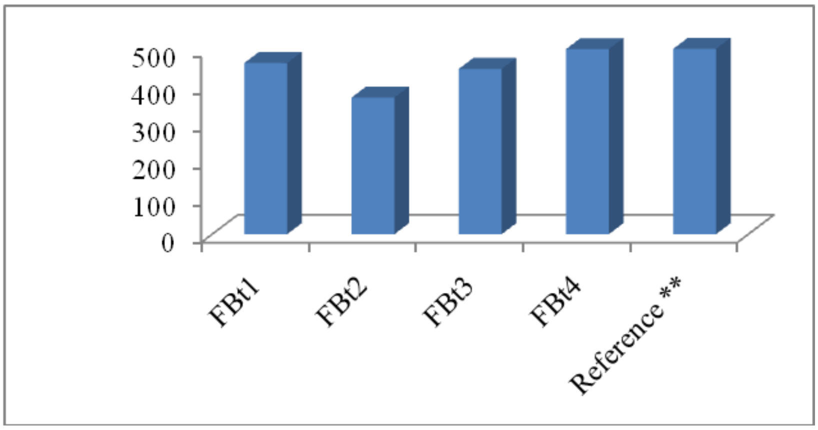


Figure 5 Modulus of rupture of fiberboards

The increase of pressing time caused the increase of MOR value. Maloney (1993) stated that one of factors that influencing the MOR value is particle geometry. MOR value of all pressing time (10, 15, 20, 25) minutes had fulfilled to JIS A5908-2003 (JSA 2003) and FAO (2013) that requirement of minimum MOR value is 100 kgcm^{-2} and maximum MOR value is 500 kgcm^{-2}.

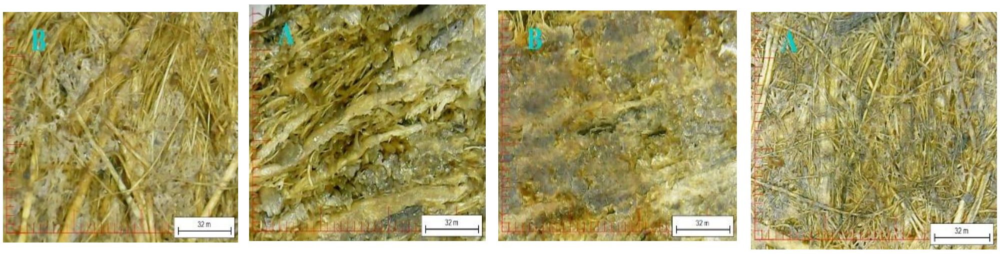
Impact strength value range of prepared fibreboard was 77.23 – 138.37 kjm^{-2}. Impact strength is the ability of a material to resist breaking under shock loading or the ability to resist the future under stressed applied at high speed.

The increase of pressing time at high temperature caused the increase of impact strength, but higher temperature for longer time caused reducing the impact strength. This condition was caused by over curing of resin. The fibreboard (FBt2) had the highest impact strength value of 138.37 kjm^{-2}.

Hardness value range of prepared fiberboards was 86.87 – 94.35 Shore A. Generally, increasing the pressing time decreases the hardness of board surface due to the longer exposure time with high temperature. Fibres on the surface cause more damage as the exposure time at high temperature is longer as expected. The fibreboard having the highest hardness value of 94.35 Shore A is (FBt2).

Surface Morphology Study of Quality Grade Fiberboards

The micrographs of reinforced coconut coir fiber UF composite fiberboards (FBt3, FBt4) are recorded by Digital Microscope (China) and shown in Figure 6. It can be observed from the micrographs that there are many micropores and microcracks on the surface and side of (FBt3). The surface of (FBt3) is also not uniform and fibers pulled out from the surface. These phenomena tend to decrease the mechanical and physical properties. The FBt4 had better quality than FBt3 due to the less micropores and cracks on the surface and more uniform of surface.



(a) Overview (a) Sideview (b) Overview (b) Sideview

Figure 6Micrographs surfaces from overview and sideview of (a) FBt3 (b) FBt4 at (300×) of magnification

Conclusion

The pressing time in fiberboard manufacturing is important factor to determine the quality of product. This is very rare phenomenon which is not observed in many of the natural fiber fiberboards. Four types of pressing time used in this research were compatible to coconut coir fiber for fibreboard manufacturing. Based on the comparison of properties of prepared fiberboards, the fiberboards (FBts) especially fibreboard (FBt4) pressed with pressing time 25 minutes had the best strength. The fibreboard (FBt4) can certainly be considered as a very promising material to fabrication of lightweight materials used in office furniture packaging industry, partition panels etc., compared to conventional wood-based poly wood or fiberboards.

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